

1 **Anthropometric and behavioral patterns associated with weight maintenance after**
2 **an obesity treatment in adolescents**

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27 **ABSTRACT**

28 **Objective** To identify anthropometric and behavioral characteristics associated with
29 weight maintenance after an obesity treatment.

30 **Study design** Seventy-two adolescents enrolled in a 9-month obesity treatment were
31 followed 1 and 2 years after discharge. Two equally distributed groups, “successful” vs.
32 “limited or no success”, were constituted on the basis of the differences in BMI z-score
33 between inclusion and end of follow-up. Anthropometric and behavioral characteristics
34 were compared between groups.

35 **Results** Both groups showed a decrease of BMI z-score between inclusion and
36 end of follow-up: 2.09 ± 0.68 SD for the successful group and 0.65 ± 0.43 SD for the
37 group with limited or no success. Groups did not differ during treatment for any of the
38 anthropometric characteristics considered, while differences clearly appeared 1 year
39 after treatment and generally stabilized during the second year. Later adiposity rebound,
40 trend for lower BMI in the mother, and lower total energy intake, more energy at
41 breakfast, less snacking and television during follow-up were recorded in the successful
42 group.

43 **Conclusions**

44 Weight loss maintenance cannot be predicted neither by anthropometry during
45 treatment nor by behavioral characteristics at inclusion, but can already be estimated
46 1 year after discharge. Early life factors should also be taken into account for the
47 prediction of treatment outcome.

48

49 **Key words:** obesity; adolescent behavior; body composition; feeding behavior;
50 treatment outcome; sedentary behavior; early determinants.

51

52 **ABBREVIATIONS.**

53 BMI, body mass index; UFE, upper arm fat area estimate; UME, upper arm muscle area
54 estimate.

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56 **RUNNING HEAD.**

57 Weight loss maintenance in adolescents

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71 INTRODUCTION

72

73 Obesity is associated with a number of health issues, which can be physical (e.g.
74 hyperlipidemia, hypertension, infertility, cardiovascular and digestive diseases) as well
75 as psychological (e.g. depression, low self-esteem).^{1,2} Moreover, obese children have a
76 higher risk than their counterparts to be obese adults^{3,4} and, to have an increased
77 morbidity and mortality rate independently of their weight as adults.⁵ It is therefore of
78 particular importance to prevent obesity occurrence in children and adolescents.

79 When prevention is not successful, weight loss treatments are considered. These
80 treatments can have varying durations, but they consistently lead to a weight reduction
81 in children and adolescents.⁶⁻¹³ Although short term outcomes are encouraging,
82 maintaining weight loss on the long term is often difficult to achieve. Follow-up of
83 children after treatment clearly showed that, while some of them succeeded, a
84 significant number of children could not maintain weight loss within one or two years
85 after the end of treatment.^{6,12,14,15} Although it is difficult to give specific figures on
86 treatment outcome, since they strongly depend on evaluation methods and duration of
87 follow-up, it seems that treatment results are generally not satisfactory.^{16,17} A significant
88 amount of work is therefore required to improve long-term maintenance of pediatric
89 obesity.

90 Among adults, successful long-term weight loss maintainers have been shown to share
91 common behavioral strategies, including eating a diet low in fat, frequent self-
92 monitoring of body weight and food intakes, and high levels of regular physical
93 activity.¹⁸ Current data on the characteristics involved in the long-term weight loss
94 maintenance in adolescents are however limited and need to be further investigated.
95 While weight and/or body mass index (BMI) are the main outcome in most studies,

96 additional anthropometric indicators, which allow a better assessment of body
97 composition and predict associated risk factors, should be included.¹⁹
98 We previously reported the influence of 9 month weight-reducing diets containing
99 different amounts of protein and CHO on body composition in obese adolescents and
100 examined dietary and physical activity behavior of the whole group during a 2 y follow-
101 up.¹² In the present study, we compared body characteristics and behavioral patterns in
102 two groups of adolescents according to weight loss maintenance over a 2-year follow-
103 up. In addition, we aimed to evaluate the time when groups differentiated, whether
104 before, during or after treatment.

105

106 **METHODS**

107

108 **Subjects**

109 This study has been described in details elsewhere.¹² Briefly, 121 obese adolescents,
110 aged 11 to 16 years, were enrolled in a weight-reducing program lasting 9 months
111 beginning in September 1997. The treatment included controlled diet, physical exercise
112 and psychological support. Of the adolescents included, 99 (29 boys, 70 girls, aged 14.3
113 ± 1.2 years) completed the whole treatment. A total of 72 adolescents were included in
114 the follow-up study 1 and 2 years after the end of treatment. Adolescents lost to follow-
115 up did not differ significantly in term of sex, age and BMI at the beginning and end of
116 treatment compared to adolescents remaining in the study. The study was approved by
117 the Ethical Committee for the protection of persons participating in biological
118 experimentation (Hospital Paris Saint-Louis) and adolescents and their parents gave
119 written consent to participate.

120

121 **Behavioral variables**

122 *Diet*

123 The 72 adolescents considered in this study had a mean stay at the center of 9 months
124 and 12 days. Daily energy intake was limited to 1750 kcal until adolescents had reached
125 a body weight goal determined by the physician. Later on, energy intake increased
126 gradually, in 1-week steps, up to 2200 kcal a day on average (depending on age and
127 sex). This diet was then maintained until the end of treatment. The study was first
128 planned to compare the influence of weight-reducing diets containing different amounts
129 of protein and carbohydrates on body composition in obese adolescents and to examine
130 dietary and physical activity behaviors during follow-up.¹² One diet (P⁻) included 15%
131 protein and 54% carbohydrate whereas the other diet (P⁺) included 19% protein and
132 50% carbohydrate. The two diets included a similar amount of fat (31%). In both cases,
133 energy distribution over the day was as follow: 20% at breakfast, 31% at lunch, 16% at
134 the afternoon snack and 33% at dinner. Snacking in addition to these four main meals
135 was very occasional in the center. Adolescents were advised to maintain a balanced diet
136 and the same energy level during week-ends and holidays as well as after the end of
137 treatment. Nutrition and in particular, total energy intake, nutrient repartition and daily
138 energy distribution, was evaluated at inclusion in the center and at 1- and 2-year follow-
139 up at adolescent home. Assessment was carried out by dieticians using the dietary
140 history method.^{20,21}

141

142 *Physical activity and sedentary behavior*

143 In the center, adolescents practiced 7h/week of vigorous sports including swimming,
144 tennis, handball, and aerobic, and 7h/week of outdoor activities including walking and
145 playing. They had no possibility to watch television or play video games but were

146 offered other activities such as reading, acting, and singing. They were advised to
147 maintain physical activity when outside the center, and after the end of treatment.
148 Physical activity (hour/week of regular sport or other activities) and sedentary behavior
149 (hour/week watching television or playing computer) were evaluated at inclusion in the
150 center and at 1- and 2-year follow-up at adolescent home. Assessment was carried out
151 by dieticians using a questionnaire²² adapted for French children.²³

152

153 **Anthropometry**

154 Adolescent weight was obtained in light clothing (dress or shorts, T-shirt) on an
155 electronic scale to the nearest 100 g (Testut, France). Height was measured with a wall-
156 mounted stadiometer (Agencinox, France) and recorded to the nearest 1 cm. During
157 follow-up, weight was measured with an electronic scale to the nearest 100 g
158 (Terrailon, France) and height with a portable stadiometer to the nearest 1 cm (Raven
159 Equipment Limited, UK). Triceps skinfold thickness was recorded at the triceps on the
160 right arm with a Harpenden caliper to the nearest 0.2 mm. All body measurements were
161 performed using standard procedures.^{24,25} BMI was computed ($\text{weight}/\text{height}^2$). Total
162 upper arm area (TUA) was calculated ($\text{midupper arm circumference}^2/4\pi$) using the
163 Jelliffe and Jelliffe principle.²⁶ Upper arm fat area estimate (UFE) (arm
164 $\text{circumference} \times (\text{triceps skinfold}/2)$) and upper arm muscle area estimate (UME) ($\text{TUA} -$
165 UFE) were derived from TUA following the Rolland-Cachera et al. formula.²⁷ This
166 method has been shown to be particularly accurate in the case of obese children and
167 adults^{27,28} compared to the Jelliffe and Jelliffe's method²⁶ that overestimates muscle
168 area. Individual BMI growth curves were drawn based on data (length/height and
169 weight) from adolescent's health booklet. Health booklets are given for all newborns in
170 France by the Ministry of Health, and aim at recording anthropometry and health events

171 occurring during childhood. Age at adiposity rebound corresponding to the nadir in the
172 BMI growth curves²⁹ was estimated visually as recommended by Kroke et al.³⁰

173

174 **Statistics**

175 Z-scores were computed for all body characteristics as they allow accounting for the
176 confounding effect of growth. Z-scores of BMI, triceps skinfold thickness, UFE and
177 UME were based on French reference data.^{27,31} LMS values using the Cole et al.
178 method^{32,33} were used for BMI and triceps skinfold thickness. Z-scores of waist
179 circumference and waist/hip ratio were based on data from the ELANCE French
180 cohort.³⁴

181 Difference in BMI z-score between the beginning of treatment and the end of follow-up
182 was calculated. Adolescents were categorized in two groups, i.e., “success” vs. “limited
183 or no success”, based on this difference. Successful adolescents were defined as those
184 having a BMI z-score reduction above the median (≥ 1.24 standard deviation (SD)),
185 whereas those with limited or no success had a z-score difference below the median
186 (< 1.24 SD). Two-tailed Student’s t-test was used to determine differences in
187 quantitative physical and behavioral variables between groups. Chi-square test was used
188 for categorical data analysis. Pearson correlations were calculated to evaluate the linear
189 relationship between BMI z-scores values and individual variables. A *P* value of less
190 than .05 was considered statistically significant. The two groups differing in protein
191 content (P^- and P^+) established in the original design were combined in the present
192 analysis since no differences in body measurements were found during treatment and
193 follow-up between the two groups. In addition, an equivalent number of subjects from
194 both diet groups were found in the “success” (18 subjects from each diet group) and in
195 the “limited or no success” (17 subjects from P^- vs. 19 subjects from P^+) groups.

196 Statistics were performed using SPSS for Windows (Release 12.0.1., SPSS Inc.,
197 Chicago USA).

198

199 **RESULTS**

200 The mean BMI z-score decrease between inclusion and the end of follow-up, was 1.37
201 ± 0.92 SD in the whole sample. The reduction was 2.09 ± 0.68 SD in the successful
202 group and 0.65 ± 0.43 SD in the group with limited or no success. Changes in z-scores
203 of the different body measurements are shown in Fig. I for both groups.

204

205 At inclusion and at the end of treatment, groups did not differ significantly for any of
206 the anthropometric characteristics considered, i.e. BMI, triceps skinfold, waist
207 circumference, waist/hip ratio, UFE and UME. In both groups, all characteristics
208 decreased sharply during treatment ($P < .001$), with the exception of UME, which
209 increased ($P < .05$). After discharge, differences in anthropometric characteristics
210 between the two groups cleared appeared. In the successful group, BMI, triceps skinfold
211 and UFE slightly increased during the 2-year follow-up while waist circumference
212 remained at the same level. In this group, all these indicators remained lower at the end
213 of follow-up than at inclusion ($P < .001$). On the other hand, in the group with limited
214 or no success, main changes in these body characteristics appeared in the first year of
215 follow-up and were less marked afterwards. In this group, BMI remained lower at the
216 end of follow-up than at inclusion ($P < .01$), whereas other indicators did not differ
217 significantly ($P > .05$). Waist/hip ratio decreased during the first year of follow-up in
218 the successful group, while it stabilized in the group with limited or no success. Values
219 were lower at the end of follow-up than at inclusion for both the successful group

220 ($P < .001$) and the group with limited or no success ($P < .05$). In the case of UME,
221 values at 2-year follow-up were not different than at inclusion in both groups ($P > .05$).
222

223 Characteristics known to be associated with adolescent obesity are shown in Table I.
224 Adolescents had a mean adiposity rebound occurring early (2.4 years) and even earlier
225 in the case of adolescents with limited or no success. Mothers of successful adolescents
226 tended to have a lower BMI than in the other group. There was no other group
227 difference.

228
229 At admission in the center, adolescent energy intake, nutrient and daily energy
230 distribution, as well as the practice of regular sport were comparable ($P > .05$ for all
231 measurements). In addition, both groups included a similar proportion of adolescents
232 who had followed a restrictive diet prior to the treatment ($P = .63$). After treatment, and
233 in particular at 2-year follow-up, successful adolescents had lower energy intake than
234 those with limited or no success (Table II). At 2-year follow-up they consumed less
235 energy from protein (-29.6 kcal), from fat (-151.2 kcal), and particularly from
236 carbohydrates (-234.8 kcal), corresponding to a different energy distribution with a
237 higher proportion of protein. In term of daily energy distribution, the successful group
238 had a greater contribution of lunch and breakfast. Adolescents who did not usually have
239 breakfast were 4 to 5 times fewer in the successful group than in the other group, at 2-
240 and 1-year follow-up, respectively. Successful adolescents snacked significantly less
241 than the others. Adolescents in the two groups did not differ in the practice of regular
242 sport nor of other activities. However, successful adolescents spent less time watching
243 television or using a computer than the other group suggesting a less sedentary
244 behavior.

245

246

247 **DISCUSSION**

248

249 In the present study, factors associated with long-term weight maintenance after a 9-
250 month weight loss treatment were examined.

251

252 Adolescents in both groups had a significantly lower BMI at 2-year follow-up than at
253 the beginning of treatment, with about two-thirds of the subjects showing a decrease in
254 BMI greater than 1 SD. This persistence of weight loss is encouraging since after
255 treatment, the adolescents had less support and were exposed to numerous factors likely
256 to compromise their ability to maintain their weight loss. It was previously shown by
257 other authors that children and adolescents are able to maintain some of their weight
258 loss after 1 year¹³, 5 years³⁵ or 10 years³⁶ of follow-up, and do better than adults³⁷,
259 although other studies emphasized the considerable relapse after weight reduction
260 programs in children and adolescents.^{16,38}

261

262 Body measurements were not different in the successful group and in the group with
263 limited or no success, neither at the beginning nor at the end of treatment. In addition, at
264 admission in the center, indicators of behaviors i.e. energy intake, nutrient and daily
265 energy distribution, as well as physical activity, were comparable. This result shows that
266 adolescents have the same likelihood to maintain their weight loss after leaving the
267 center independently of their body measurements and behavioral pattern at inclusion
268 and their weight loss during treatment. In contrast, other authors showed that weight
269 loss maintenance was more likely in less obese than in heavier individuals.³⁹

270

271 Many authors emphasized the great variation in individual responses to treatment during
272 follow-up.^{9,40} In our study, differences between groups appear when adolescents leave
273 the center and come back in their family environment. Anthropometric differences were
274 clearly visible in the first year after the end of treatment. In the second year, a
275 continuous increase was observed for some body characteristics (e.g. waist
276 circumference), while for others the increase was less marked (e.g. BMI) or even
277 nonexistent (e.g. triceps skinfold thickness). These results suggest that the first year is
278 particularly critical for fat mass regain and that anthropometry at 1-year follow-up is a
279 good predictor of long-term weight loss maintenance. In agreement, Snethen et al.¹⁷
280 recommended that weight loss programs for children should include an appropriate
281 follow-up for at least 1 year, because it is known that individuals who maintain their
282 weight loss for 1 year are likely to show long-term success. In the present study, waist
283 circumference was a particularly good indicator of weight loss maintenance. This
284 measurement is particularly convenient and recommended when studying obesity
285 because of its relationship with diabetes and other diseases.⁴¹

286

287 Adolescents in the group with limited or no success were characterized by a higher
288 energy intake compared to the other group, specifically at 2-year follow-up. They
289 consumed more of all nutrients, but particularly carbohydrates including sucrose. Wing
290 and Hill¹⁸ showed that weight gainers particularly increased their fat intake compared to
291 weight maintainers. In term of daily energy distribution, in the present study, the
292 successful group tended to eat more at breakfast and lunch than the other group, and to
293 snack less. As a rule, the successful group tended to eat more during the first part of the

294 day (breakfast and lunch) than the other group. This is consistent with other studies
295 reporting altered daily rhythm in the obese.⁴²⁻⁴⁴

296

297 During follow-up, the successful group showed a less sedentary behavior than the other
298 group with significantly less time spent watching television or using computer.
299 However, the practice of sport did not differ significantly between groups. This result
300 shows that it is important to reduce sedentary lifestyle to maintain weight loss. The
301 impact of sedentary behavior on overweight and obesity was shown by numerous
302 authors⁴⁵⁻⁴⁷ and a reason proposed was the importance of snacking while watching
303 television.⁴⁸ In our study, time spent in front of the television or computers at 1-year
304 follow-up was significantly correlated with sucrose ($r = .51$, $P < .001$). Restricting
305 access to television or computers and encouraging alternative activities might therefore
306 be a promising approach to help prevent adolescent obesity or relapse after weight loss.
307 However, the importance of exercise should not be underestimated since physical
308 training is associated with beneficial changes in fat and lean body mass.^{22,49}
309 Incidentally, both groups showed a decrease of lean body mass after leaving the center,
310 probably due to a decrease in physical activity.

311

312 It is clearly established that age at adiposity rebound is associated with obesity later in
313 life and that it occurs earlier in the obese (around 3 years) than in normal subjects
314 (around 6 years).⁵⁰ Mean age at adiposity rebound in the present study was 2.4 years
315 and occurred even earlier in the group with limited or no success. In addition, mothers
316 of adolescents in the successful group tended to have a lower BMI than those in the
317 other group. It is known that children with overweight parents have a greater risk of
318 becoming overweight^{4,17,51,52} due to genetic and/or environment. An early adiposity

319 rebound and high maternal BMI can reflect the influence of early determinants.⁵⁰⁻⁵² The
320 influence of early life determinants in weight loss maintenance after treatment should
321 therefore not be underestimated. Besides, mother weight can reflect family habits. Thus,
322 family therapy and involvement could be used as improving the support for the child by
323 the family.^{53,54}

324

325 This type of intervention lasting a few months can present some disadvantages.
326 Adolescents are supervised over a long period and it can be difficult for them to follow
327 an adequate diet without control, after leaving the center. On the other hand, the long
328 period of treatment is likely to favor an imprinting of positive behaviors. The long
329 follow-up in this study presents the advantage to give a good indication of the long term
330 success of treatment, although the drop-out rate may limit the interpretation of the
331 results. Finally, it must be noted that there is no consensus on what method should be
332 used to evaluate success of weight loss maintenance. Success or failure is likely to differ
333 according to the method selected. We defined success of weight loss maintenance using
334 z-score differences between the end of follow-up and the beginning of the study. This
335 method is now increasingly used for this type of evaluation.^{10,15}

336

337 **Conclusion**

338 This study identifies factors related to long-term outcome of weight loss treatment in
339 obese adolescents. Neither behavior at inclusion nor body measurements before and
340 during treatment were associated with weight loss maintenance over a 2-year follow-up.
341 Rather, the difficulty in maintaining weight loss seemed to be related to the difficulty in
342 making permanent changes in dietary and sedentary behaviors after treatment. Some
343 adolescents were able to make life-style changes following advice received during

344 treatment, while others were not. Weight loss maintenance was also related to the
345 child's age at adiposity rebound and mother's BMI, highlighting the importance of early
346 life determinants as well as the importance of the family environment. The fact that, in
347 the present study, a large proportion of adolescents were able to maintain their weight
348 loss is encouraging. More research is required to identify the factors associated with
349 treatment outcome in order to improve long-term maintenance of weight loss in obese
350 adolescents.

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509 **Fig. I**

510 Changes in body characteristics z-scores in the successful group (—) and in the group
511 with limited or no success (---) at 4 examination points: inclusion (T_0), end of treatment
512 (T_{end}), 1 (F_{1y}) and 2-year (F_{2y}) follow-up after treatment. Differences between groups
513 are shown: *ns* non-significant, * $P < .05$, ** $P < .01$, *** $P < .001$.
514 BMI: body mass index, UFE: upper arm fat area estimate, UME: upper arm muscle area
515 estimate.